3.3 MONITORING MARINE WEATHER SYSTEMS USING QUIKSCAT AND TRMM DATA

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1. INTRODUCTION

We do not understand nor are able to predict marine storms, particularly tropical cyclones, sufficiently well because ground-based measurements are sparse and operational numerical weather prediction models do not have sufficient spatial resolution nor accurate parameterization of the physics. Yet, marine storms post risk to shipping, and when they land, may cause devastation with strong wind and heavy rain. Conventional satellite data only provide cloud-top image of the storm. The Tropical Rain Measuring Mission (TRMM), a joint U.S.-Japanese mission launched in 1997, only provide measurements of rain and rain profile with its microwave radiometer (TMI) and precipitation radar (PR) over the tropical oceans [Kummerow et al., 1998]. The radar scatterometer, SeaWinds, on NASA Mission QuikSCAT was launched in June 1999 [Graf et al., 1998], and is providing ocean surface wind vectors which feed moisture into the storms. The 1800-km continuous swath of SeaWinds provides unprecedented coverage, and the 25 km resolution may provide sufficient details for monitoring and analysis of marine weather systems. The widths of the ground-tracks of TMI and PR are 760 km and 220 km respectively.

This study is intended to demonstrate the potential of using the two spacebased systems together to understand the interplay between the dynamics and hydrologic parameters in marine weather systems; Hurricane Floyd provides an example. Hurricane Floyd was born around September 8, 1999 in the tropical Atlantic and moved towards the Atlantic Coast of the U.S. Its landfall around September 16 caused severe flooding and economic impact to the U.S. Our analysis is based on observations on 13 September 1999, when the Hurricane is north of the Dominican Republic.

2. THE MOISTURE BUDGET

The principle of conservation of moisture in pressure coordinate gives the apparent moisture sink Q as:

$$Q \equiv -L(\frac{\partial q}{\partial t} + \vec{u}\nabla q + \omega\frac{\partial q}{\partial p}) = L(c - e)$$

where q is specific humidity, p is the pressure, c the rate of condensation per unit mass of air, e the rate of evaporation of cloud and rain water, $\vec{u}$ is wind vector, and L is latent heat of vaporization.

Hsu et al. [1997] demonstrated that spaceborne scatterometers which provide frequent observations of surface wind vectors at high spatial resolution can be used to improve the estimation of Q in convective systems. The influence of surface level winds will be felt throughout the atmospheric column because of mass conservation. The vertical velocity ω at a given pressure level p is given by

$$\omega_p = \omega_s + \int_p^{p_s} \nabla \cdot \vec{u}dp$$

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where the subscript s refers to quantities at the surface. In this method, ω at a given pressure level depends on the horizontal velocities at that level and all levels below. Because most of the atmospheric water vapor resides near the surface, the accuracy of surface level winds is expected to outweigh upper level winds in importance, in estimating ω and Q.

If we take the vertical integral from the tropopause (p_T) to the surface (p_s) the result is:

$$< Q >= \frac{1}{g} \int_{p_T}^{p_s} Q dp = L(P - E)$$

P is the sum of moisture in a column that condenses and falls to the earth as precipitation, and E is the evaporation from the underlying ocean into the atmosphere. The computation of Q profile and P requires measurements of the vertical profiles of wind vector and humidity in the atmosphere which, traditionally, come from aerological (rawindsonde) data. Over ocean, rawindsonde data are sparse and the products from numerical weather prediction models have been used, with insufficient accuracy and resolution.

3. SURFACE PRECIPITATION

Near real-time wind vectors from SeaWinds, at 25 km spatial resolution, are interpolated to a 1/4 degree grid over Hurricane Floyd. Analysis products from the Global Data Assimilation System of the National Center for Environmental Prediction (NCEP) are extracted over the same area. The NCEP data are available at 6 hour intervals, 1 degree latitude and longitude spatial resolution, and with 17 levels between 1000-300 mb. They were interpolated to 1/4 degree to match the scatterometer wind fields before Q is computed. Due to the coarse resolution of NCEP data, Fig 1a shows that the center of the Hurricane (roughly at 24°N, 70°W) can barely be identified. The scatterometer winds, however, show the typhoon center to be at 23°N and 71°W to the southwest of the location identified by the NCEP data. By inserting the scatterometer winds at the level between 1000 and 950 mb, and recomputing $< Q >$, much more details of the hurricane are revealed (Fig. 1b), The stronger wind

convergence results in higher $< Q >$ with high values along three frontal bands, which are quite different from the $< Q >$ distribution resulted from using only NCEP data.

The comparison between $< Q >$ which is the difference between precipitation and evaporation averaged over the spatial grid and time interval (Fig. 1a and b) with the instantaneous surface precipitation estimated from TRMM observations (Fig. 1c), is difficult to interpret. Rain is much more intermittent than winds, the values estimated by TRMM are understandably higher than those of $< Q >$. The surface rainfall revealed by TRMM show clear frontal bands. The location of the eye of the hurricane is slightly to the south of that revealed by the wind patterns, most probably due to the time difference; TRMM passes over Floyd at 09 Z.

4. PROFILE OF MOISTURE SINK

The Q profile computed from NCEP data alone does not show the eye of the hurricane, nor any rainband structure (Fig. 2, bottom). By adding Sea-Winds data at the surface level, the precipitation area is increased, and three rainbands are revealed, and the location of the eye with no rain is identifiable (Fig. 2, middle). The location of the eye is slightly to east of the location identified by TRMM data (Fig. 1c). It is clear that PR has a high resolution that neither NCEP nor QuikSCAT can match.

5. DISCUSSION

We have demonstrated the possible scientific synergism of two spacebased earth observing systems of NASA. Due to the lack of validation data, the accuracy of scatterometer winds under high wind and high rain conditions is uncertain. Vigorous efforts are underway to improve wind retrievals under such conditions. A similar SeaWinds instrument will be flown in complementary orbit with QuikSCAT, on a Japanese spacecraft, ADEOS-2, to be launched in 2001. This would permit global coverage of surface wind at diurnal time-scales. A global precipitation observing satellite is being planned by NASA to follow TRMM in providing precipitation measurements. Besides measuring surface rain, TMI also

provides sea surface temperature under both clear and cloudy conditions. The combined data set will clearly advance our understanding the air-sea interaction in marine weather systems.

ACKNOWLEDGMENT

REFERENCES:

Graf, J., C. Sasaki, C. Winn, W. T. Liu, W. Tsai, M. Freilich, and D. Long, 1998: NASA Scatterometer Experiment. Asta Astronautica, 43, 397-407

Hsu, C. S., W. T. Liu, and M. G. Wurtele, 1997: Impact of scatterometer winds on hydrologic forcing and convective heating through surface divergence. Mon. Wea. Rev., 125, 1556-1576.

Kummerow, C., W. Barnes, T. Kozu, J. Shiue, and J. Simpson, 1998: The Tropical Rainfall Measuring Mission (TRMM) sensor package, J. Atmos. Oceanic Tech., 15, 809-817.
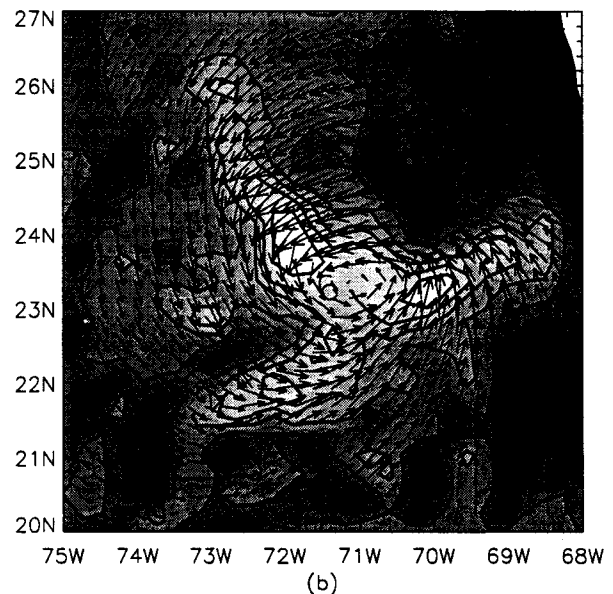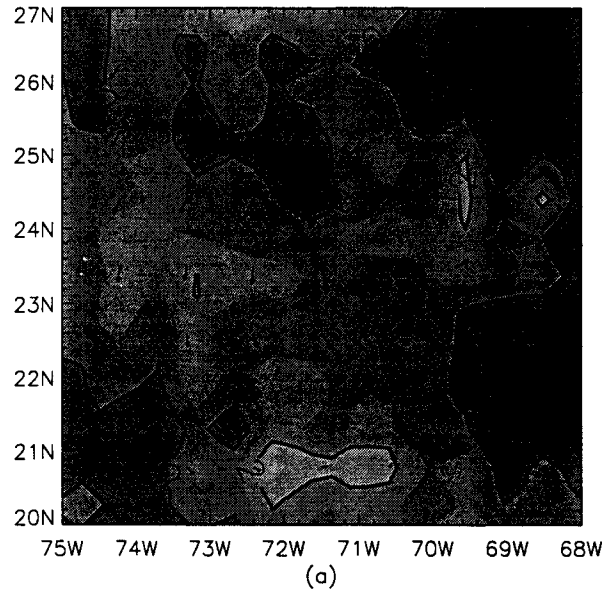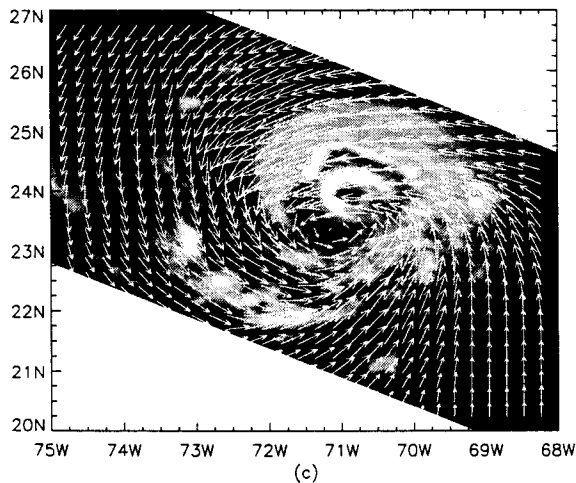

(a)

(b)

(c)

Figure 1: Surface wind vectors superimposed on precipitation estimate over Hurricane Floyd on September 13, 1999, (a) with both wind vector and precipitation (as integrated moisture sink) from NCEP data; (b) same as (a) but with wind vectors from SeaWinds, and precipitation derived by replacing low level NCEP winds with SeaWinds data; (c) with precipitation measured by TMI and winds by SeaWinds. Precipitation in units of mm/hr. In panels (a) and (b), contour intervals are 2 mm/hr. In panel (c), the brightest region indicates precipitation rates above 20 mm/hr.
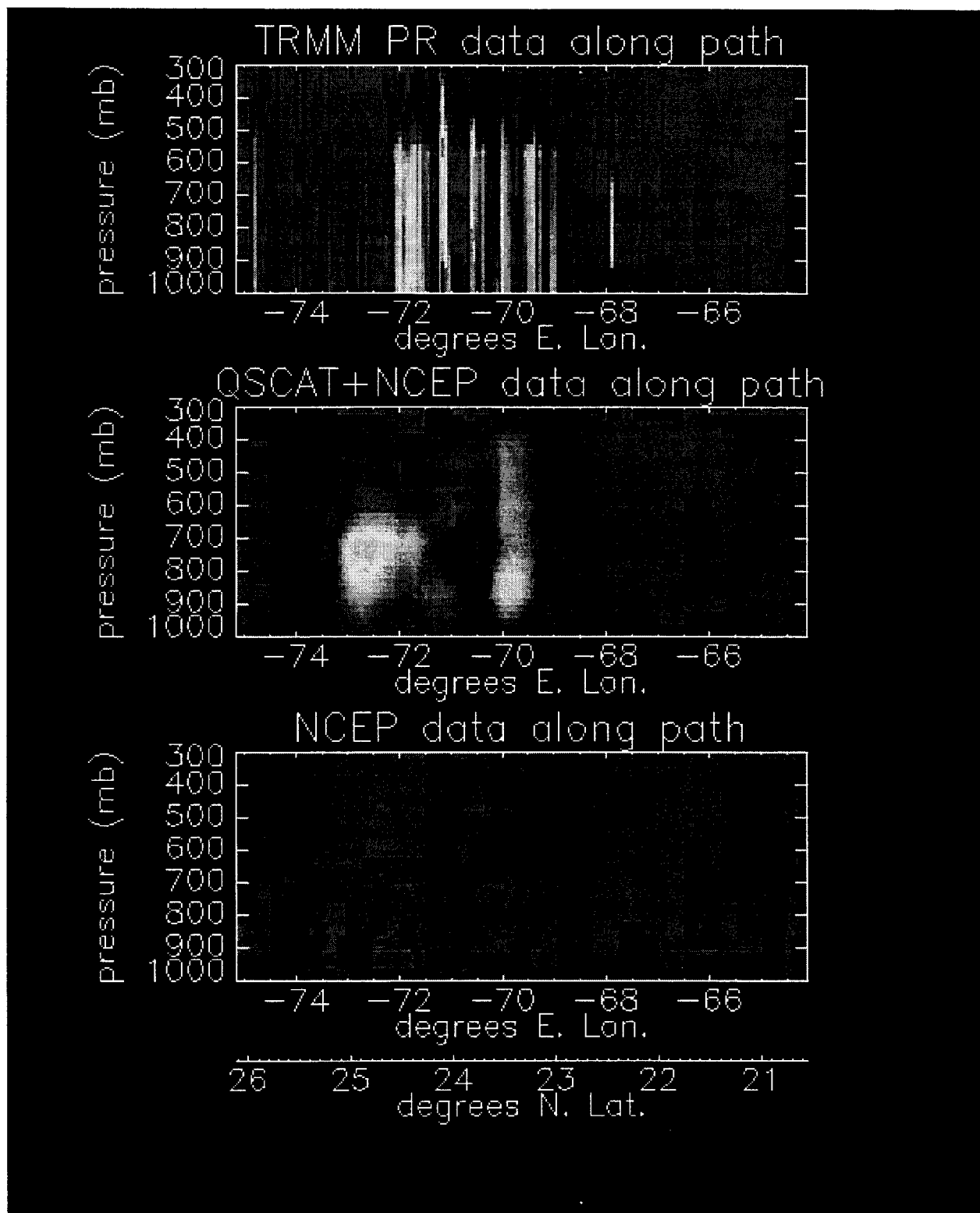
Figure 2: Precipitation profiles along the groud-track of the TRMM precipitation radar derived from: (top panel) TRMM data; (middle panel) QUICKSCAT data + NCEP; (bottom panel) NCEP.